Next Generation Starshade Missions and the Ares V

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And the New Worlds Observer Team

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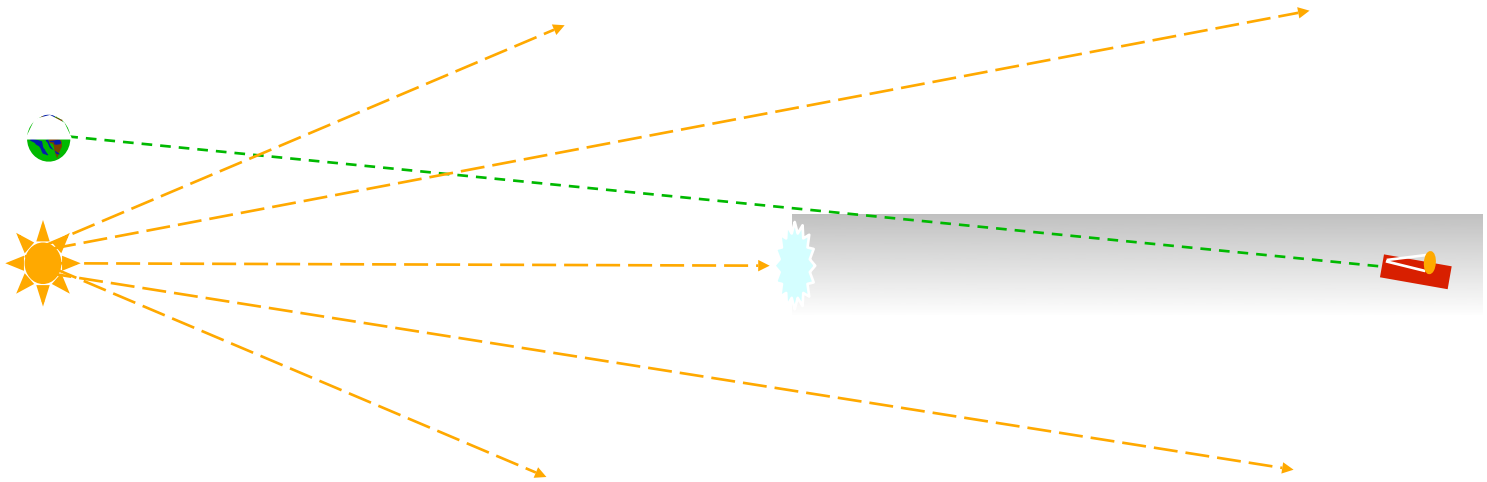
Mission Sequence

- **Planet Detection**
  - Happening now – mostly RV studies from ground.
- **Planet Finding**
  - Terrestrial Planet Problem – Ground? Or Medium Space Mission
- **Planet Characterization**
  - Flagship Space Mission - New Worlds Observer Spectroscopy
  - EELV Adequate
- **Lifefinder**
  - R~10,000 Spectroscopy
  - Large telescope (8-16 m), ATLAS-T + starshade(s), Ares V advantageous
- **Planet Imager**
  - Multiple telescopes+starshades
  - Large baseline imaging interferometry, Definitely requires Ares V

Starshade as Occulter



Telescope big enough to collect enough light from planet

Starshade big enough to block star

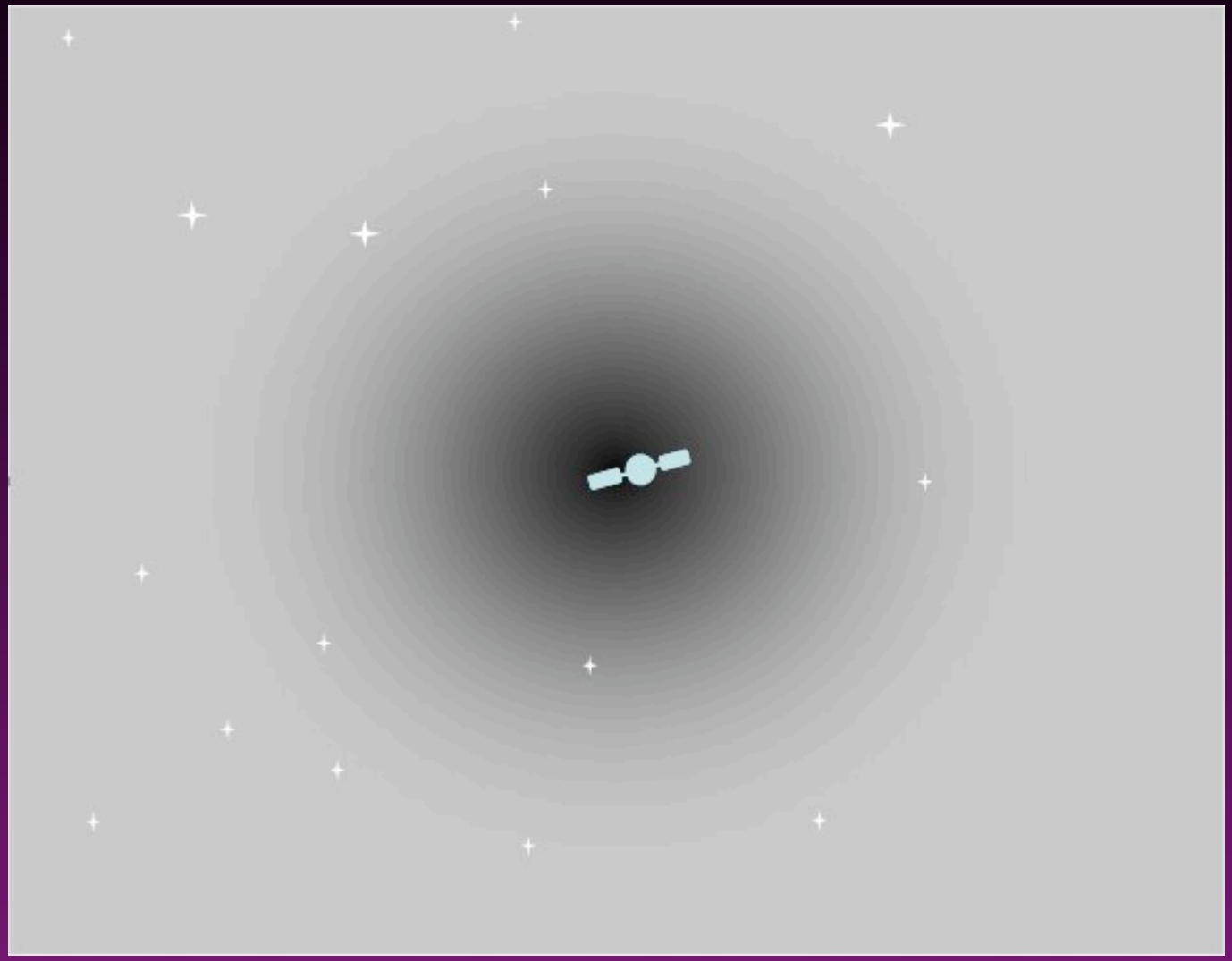
Want low transmission on axis and high transmission off axis

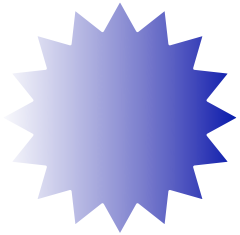
Telescope far enough back to have a properly small IWA

No outer working angle: View entire system at once

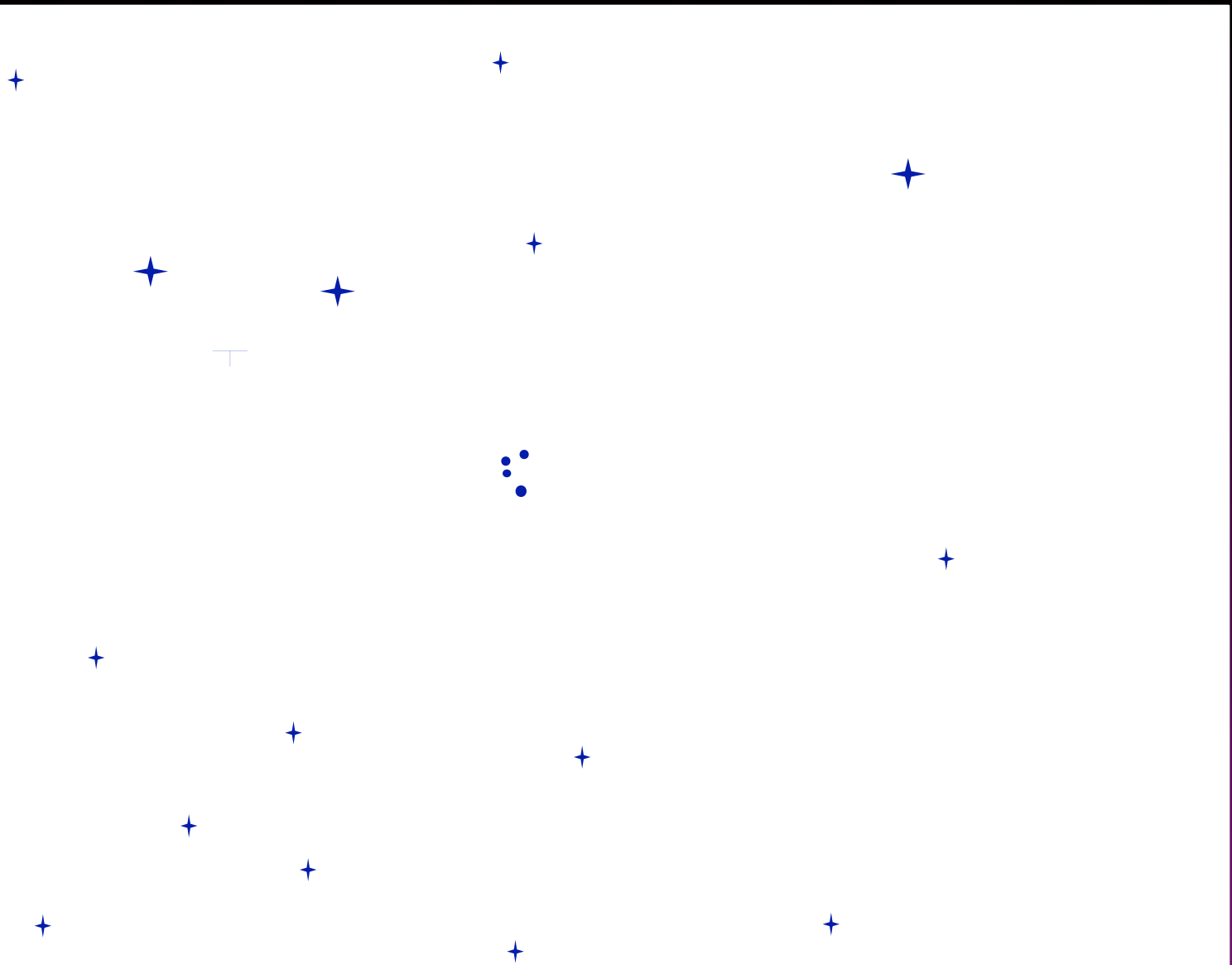
New Worlds Observer

Fly the Telescope into the Shadow





Note: No Outer Working Angle



Note: No Outer Working Angle

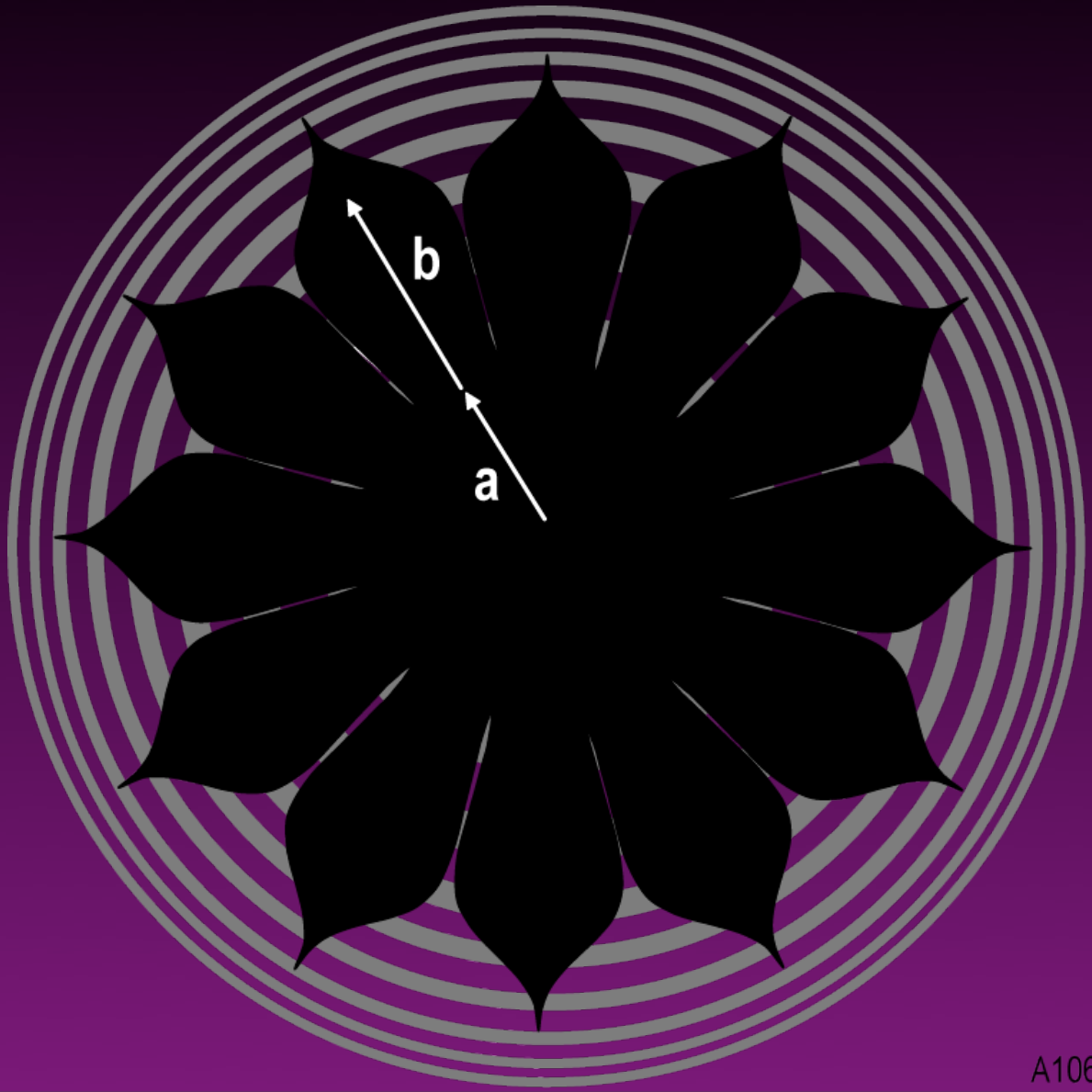
A Solution Exists

$$A(\rho) = 0$$ for $\rho < a$

and

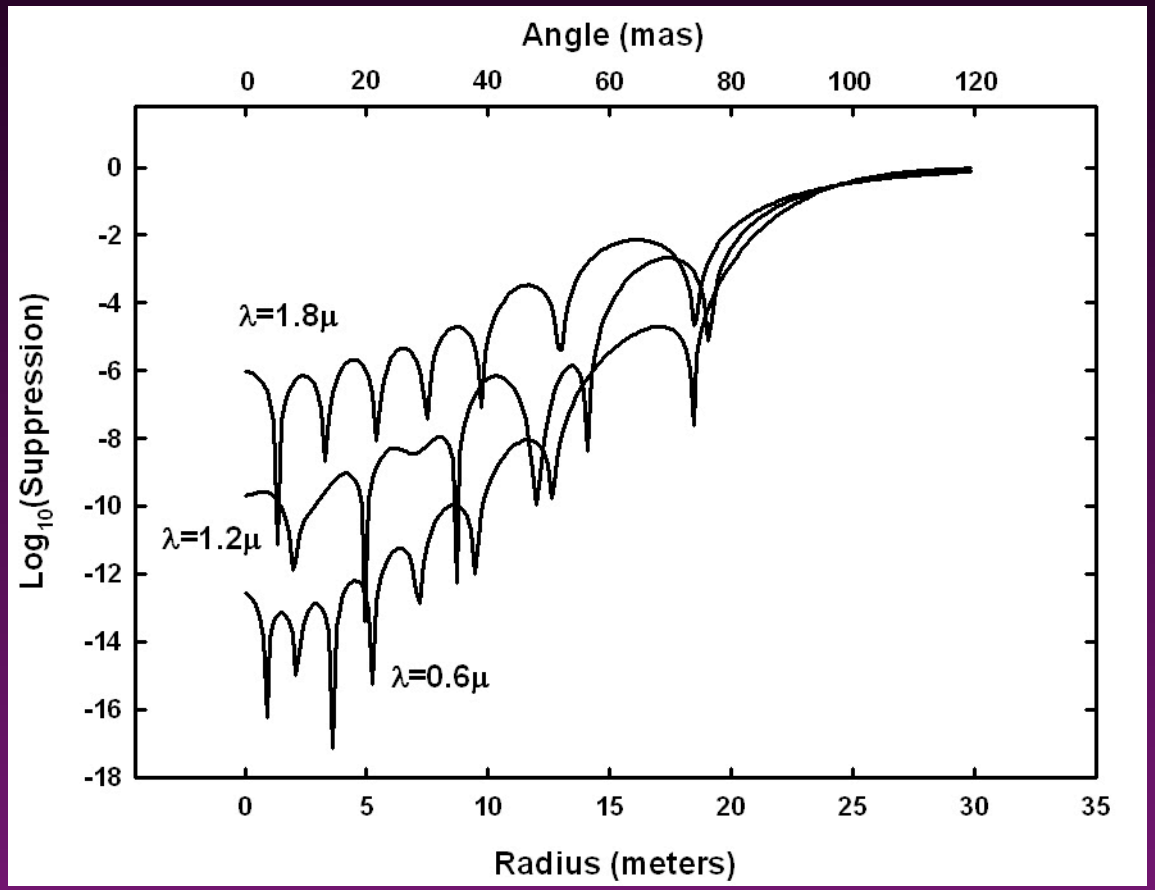
$$A(\rho) = 1 - e^{-\left(\frac{\rho - a}{b}\right)^n}$$ for $\rho > a$

Binary Shape



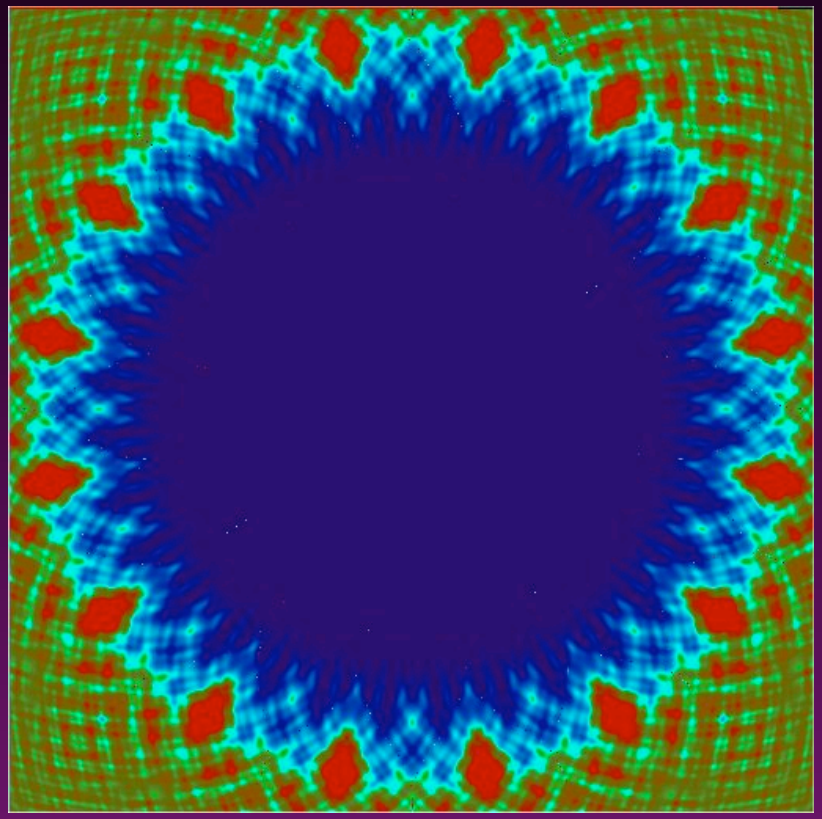
Performance

A 50m diameter occulter at 50,000km will reveal Earths at 10pc

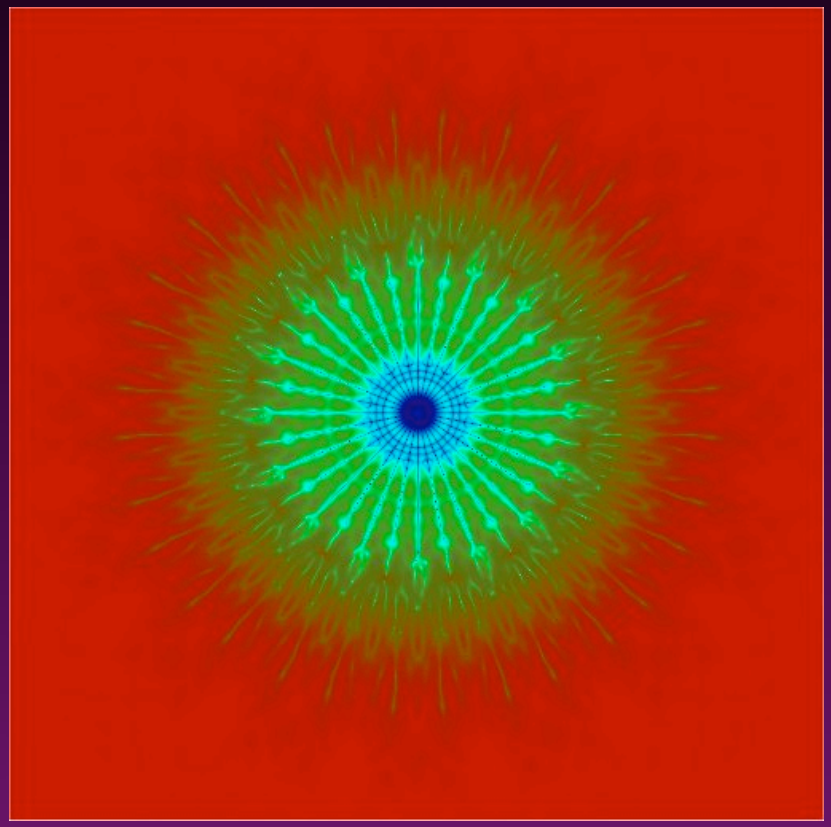


a=b=12.5m
n=6
F=50,000km

Shadow of 16 Petal Mask

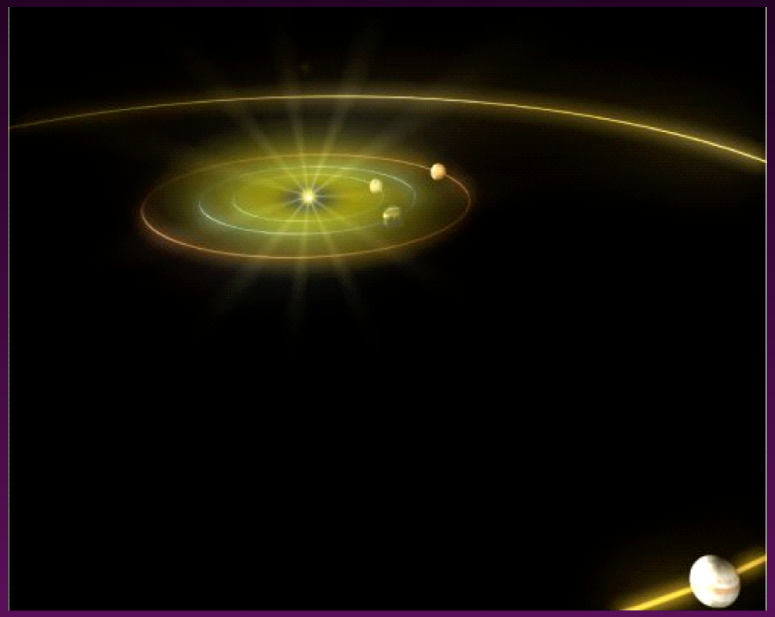


Linear



Log

Simulated Solar System



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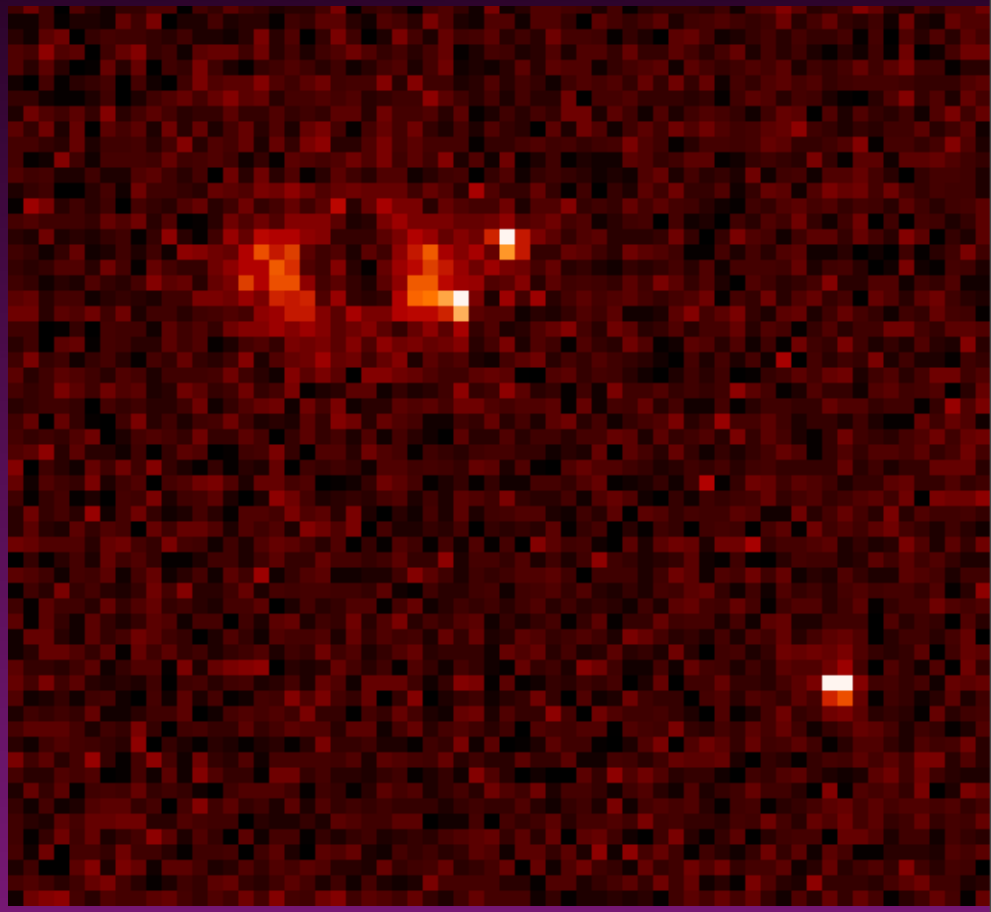
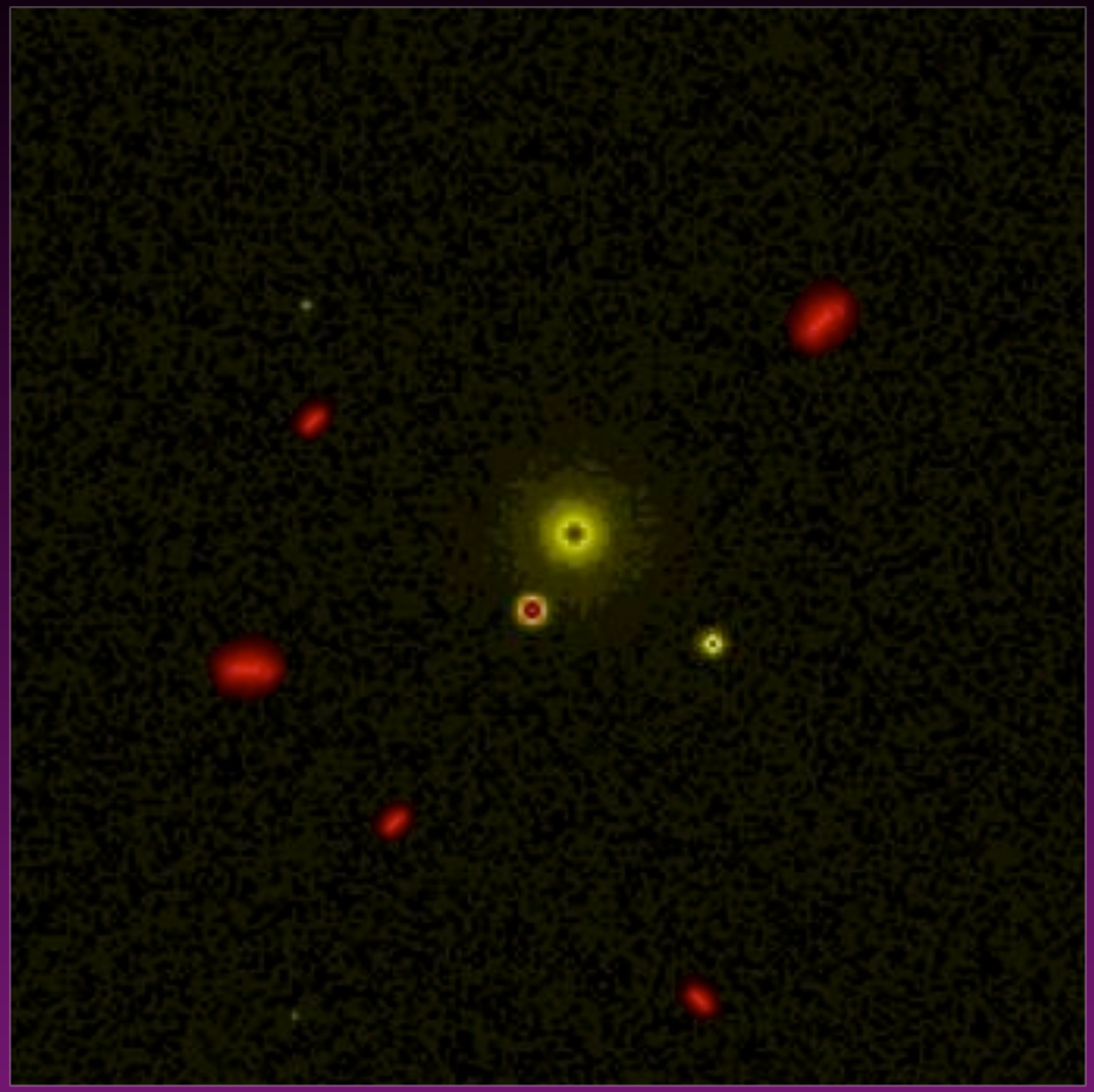
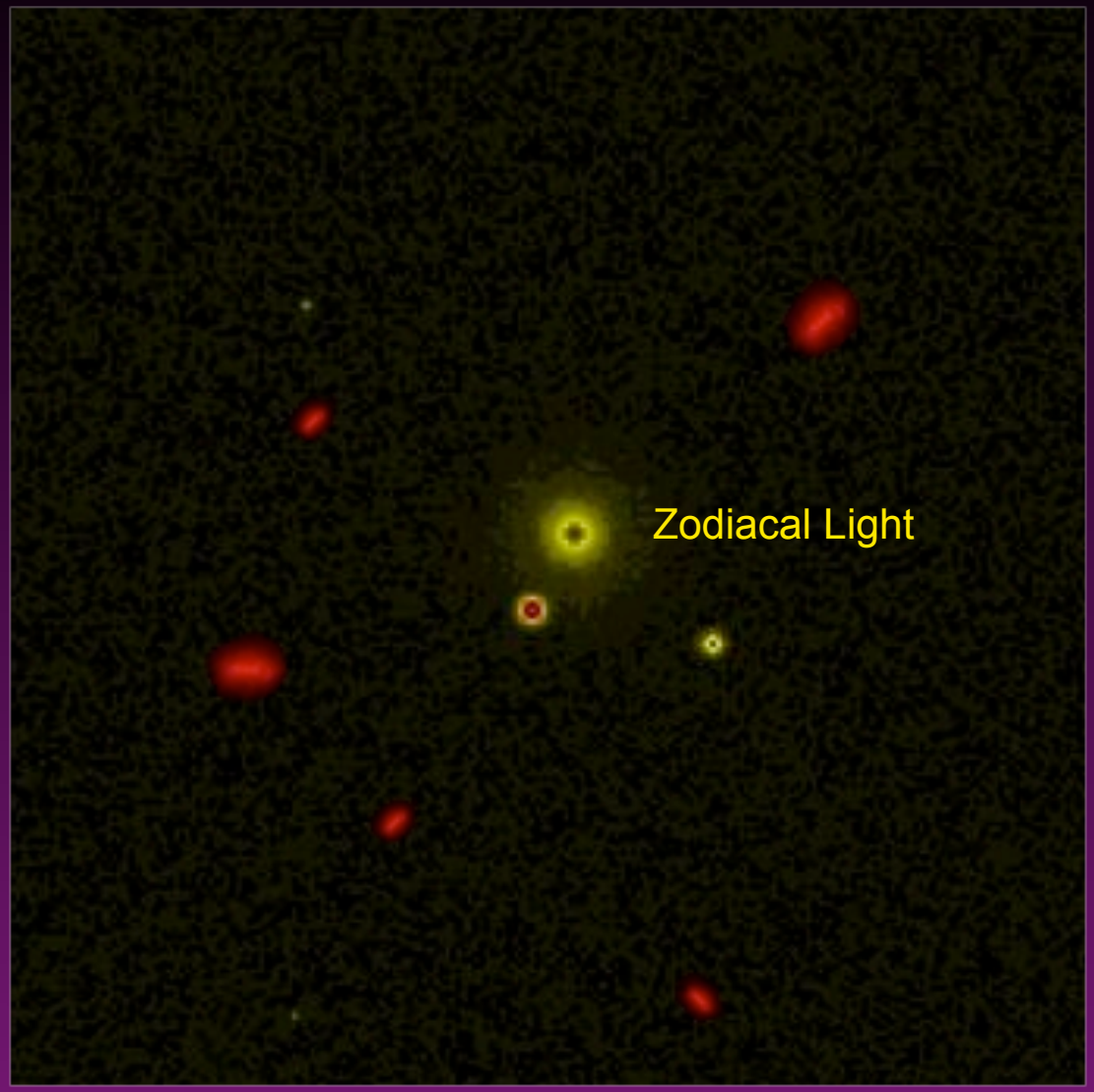


The First Image of Solar System



10 arcseconds

The First Image of Solar System



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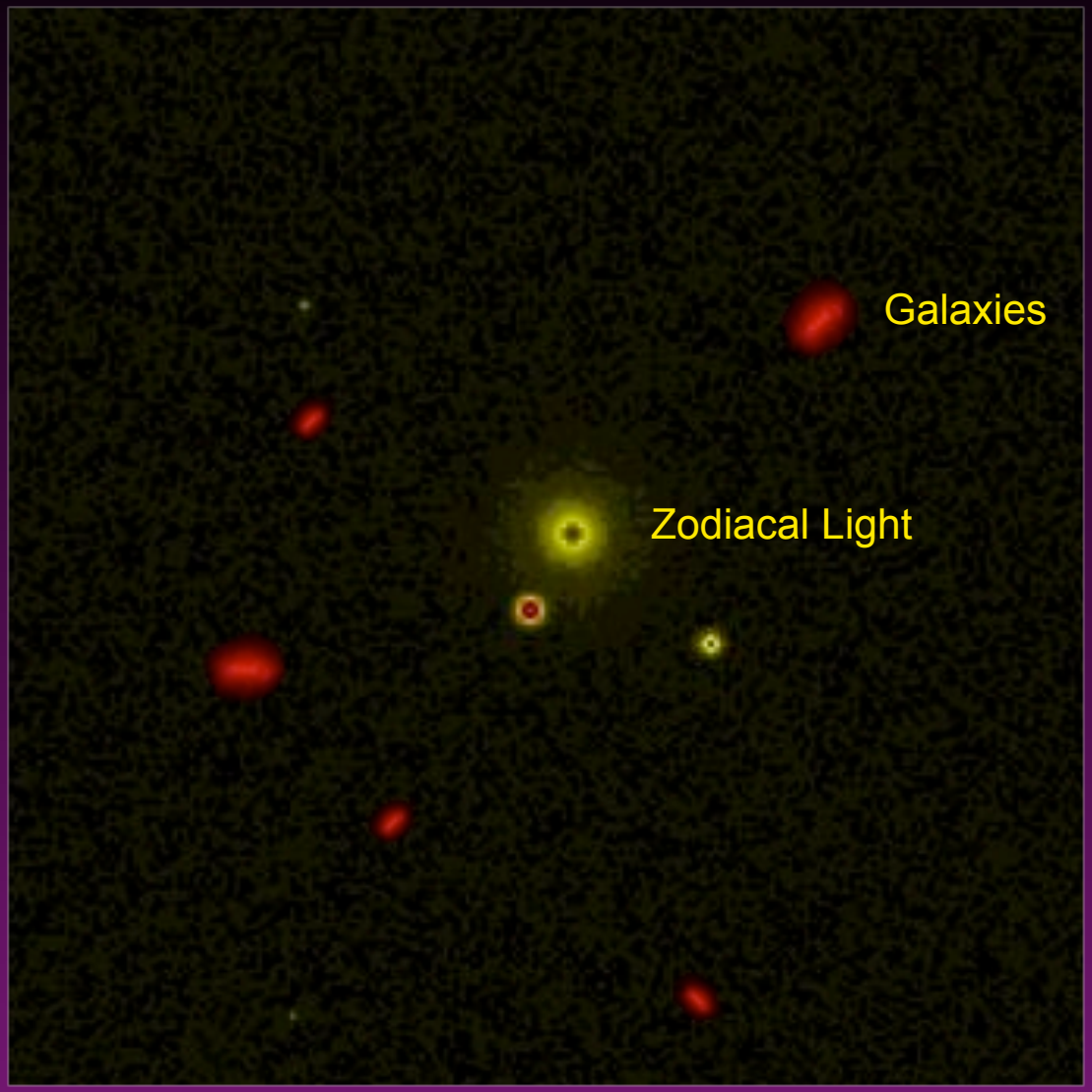

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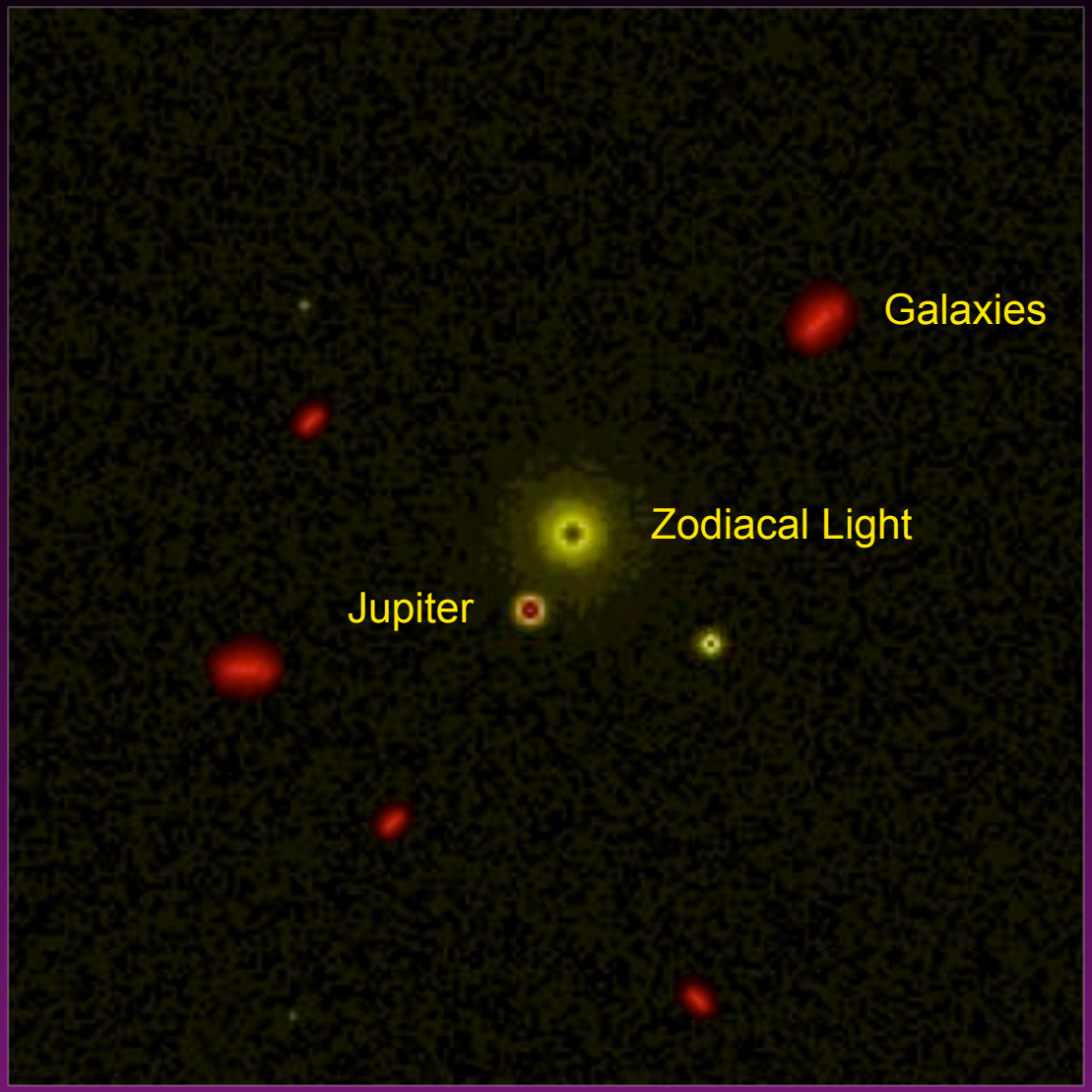

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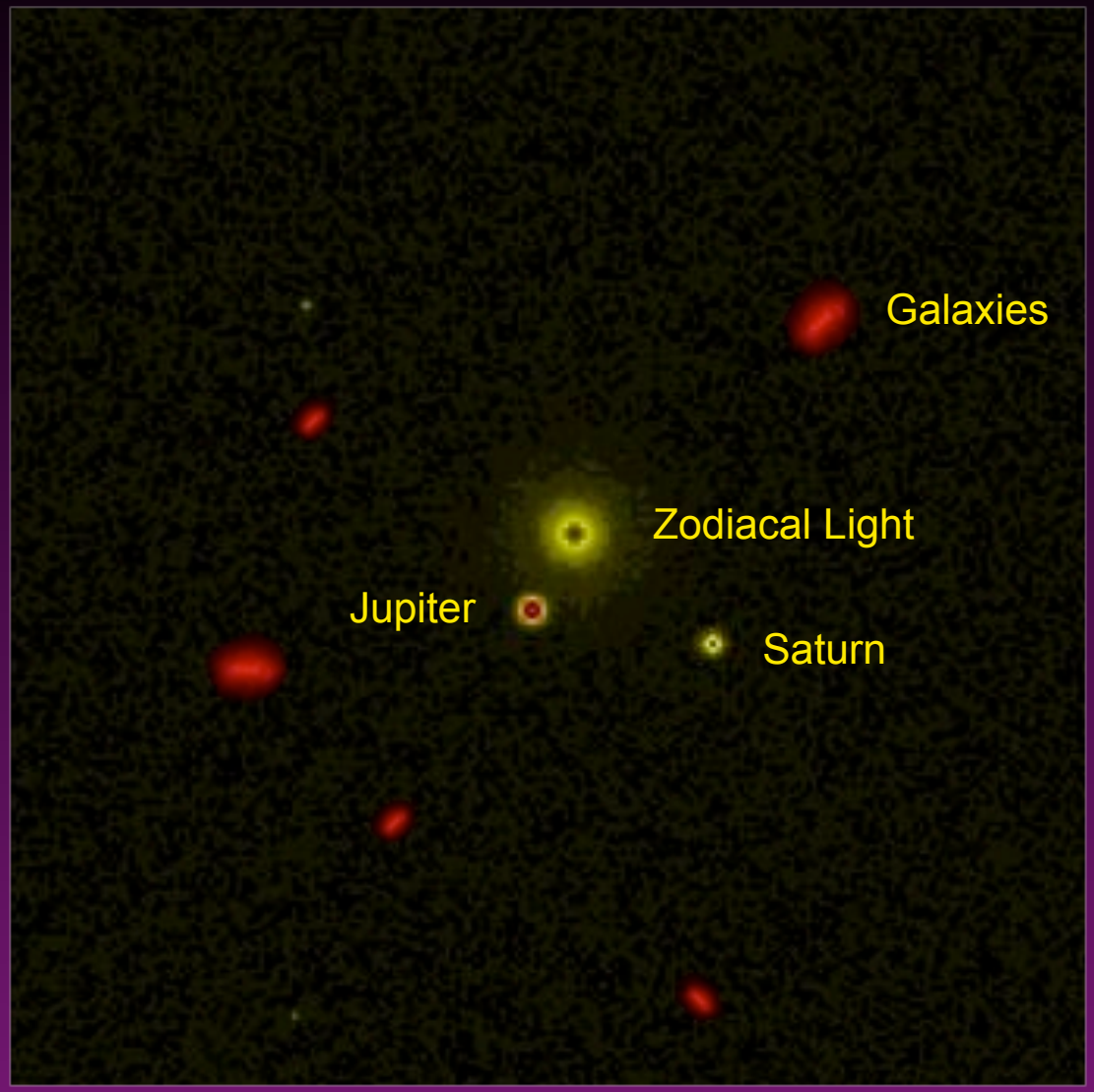

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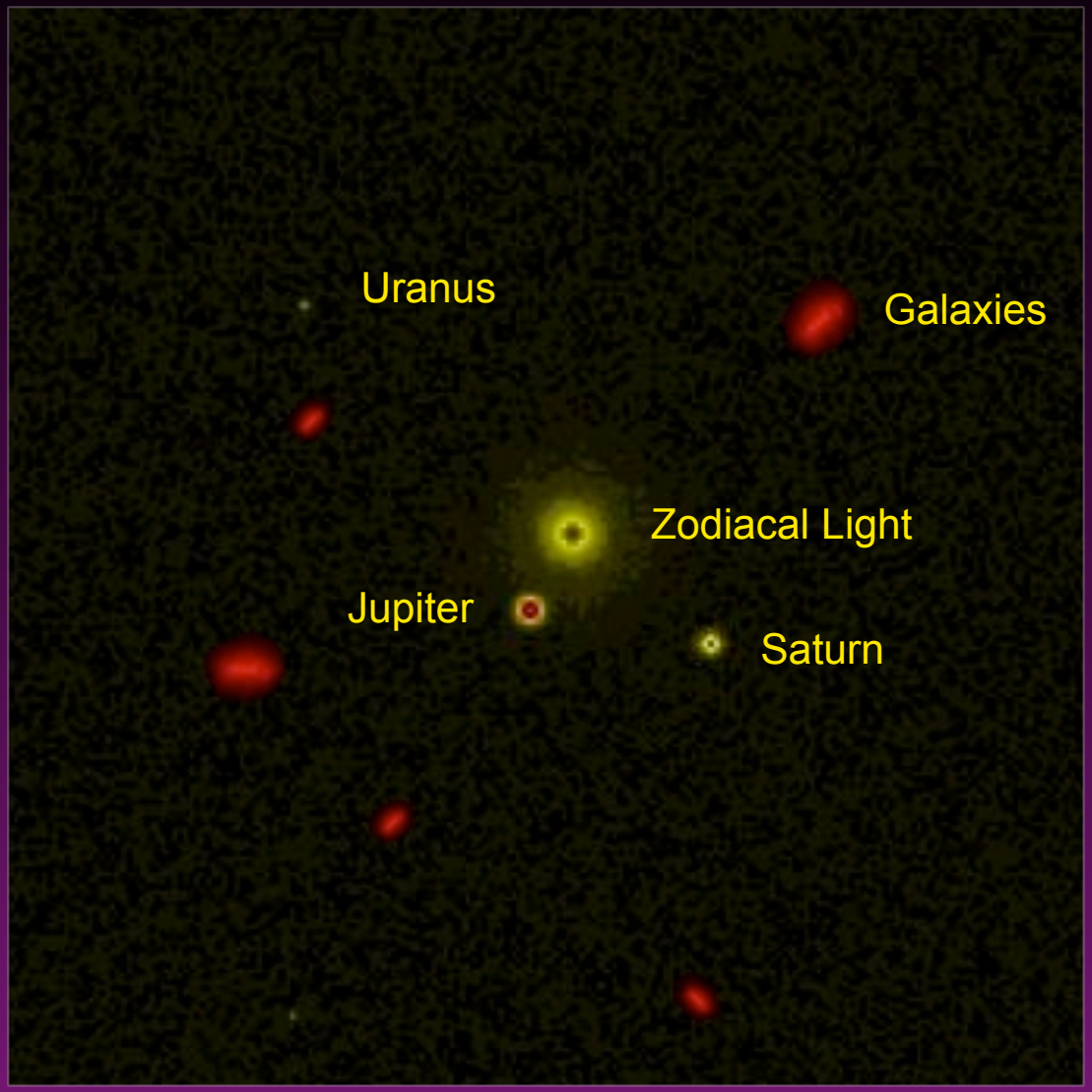

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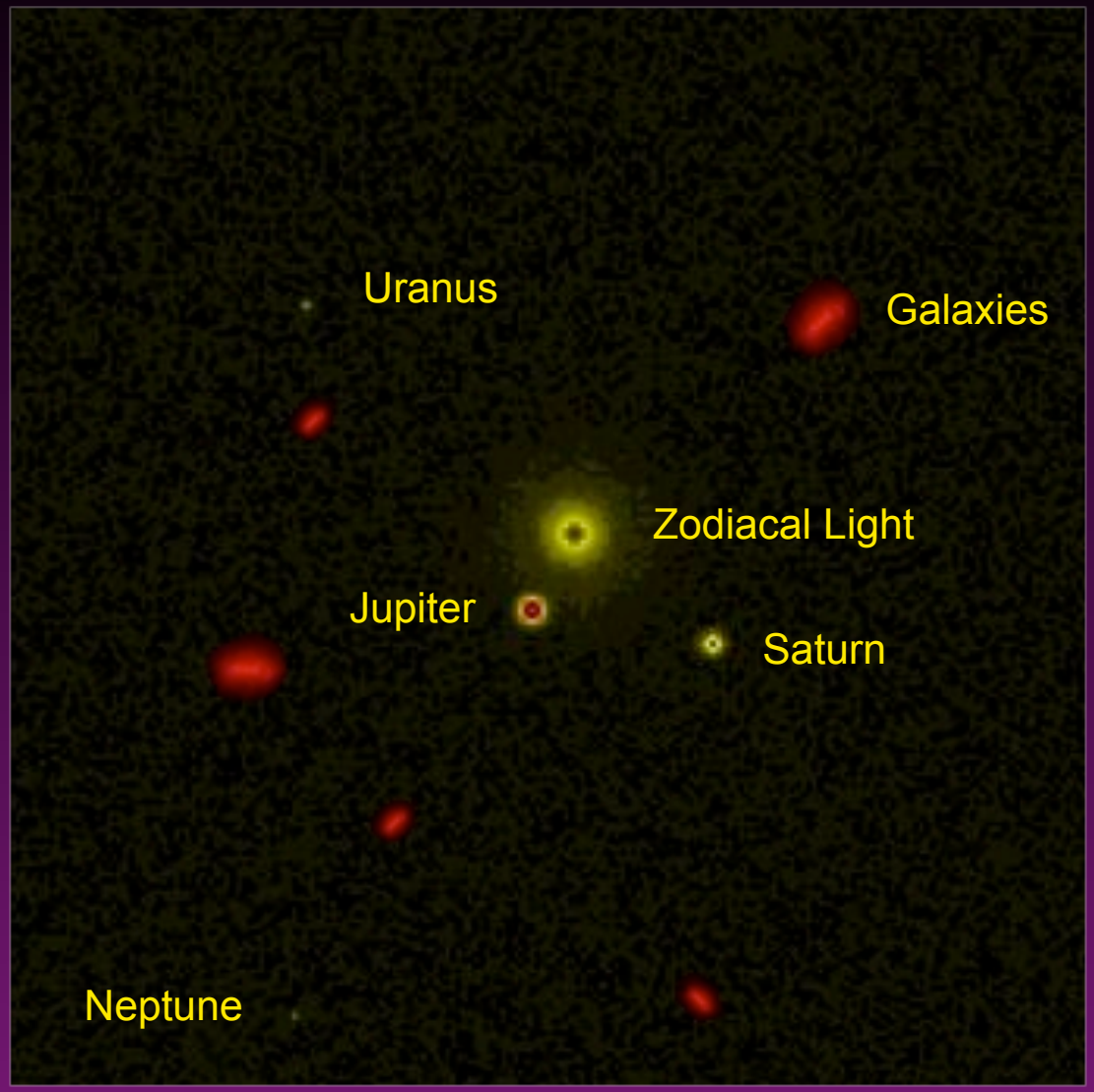
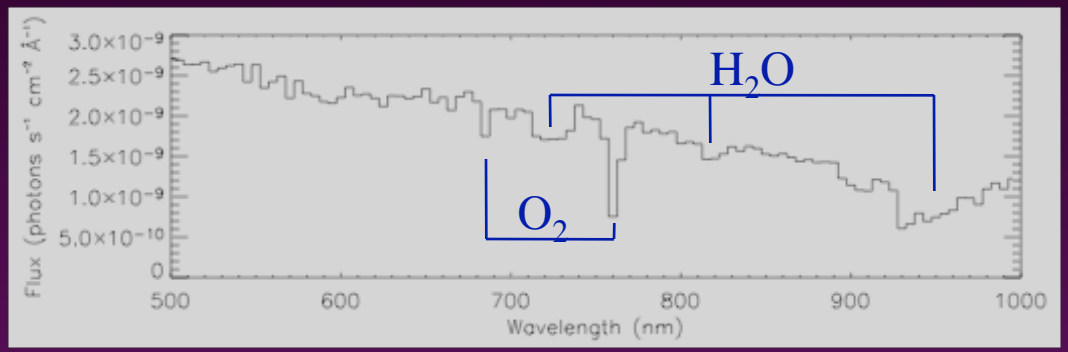
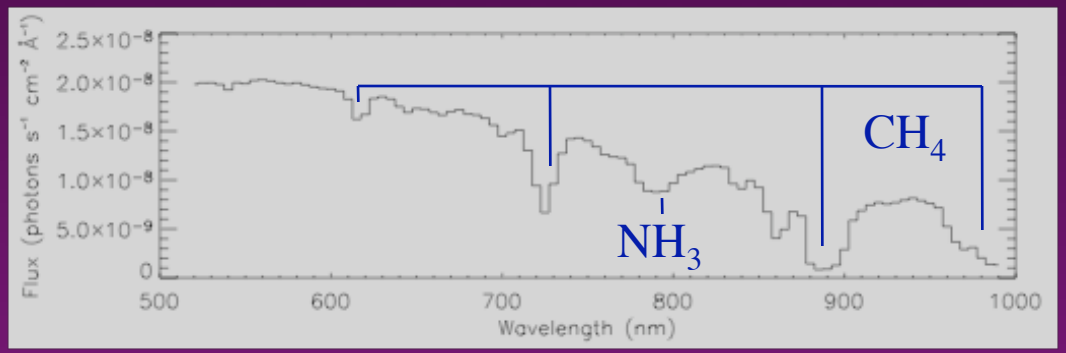
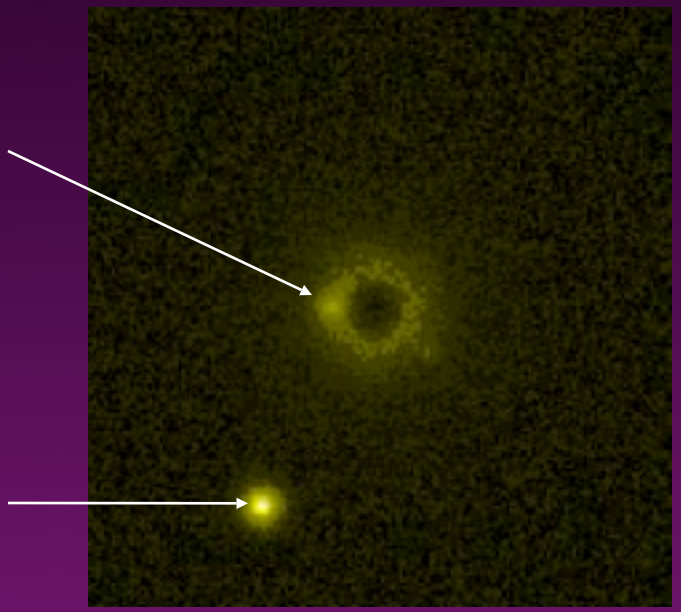


Spectroscopy

- R > 100 spectroscopy will distinguish terrestrial atmospheres from Jovian with modeling

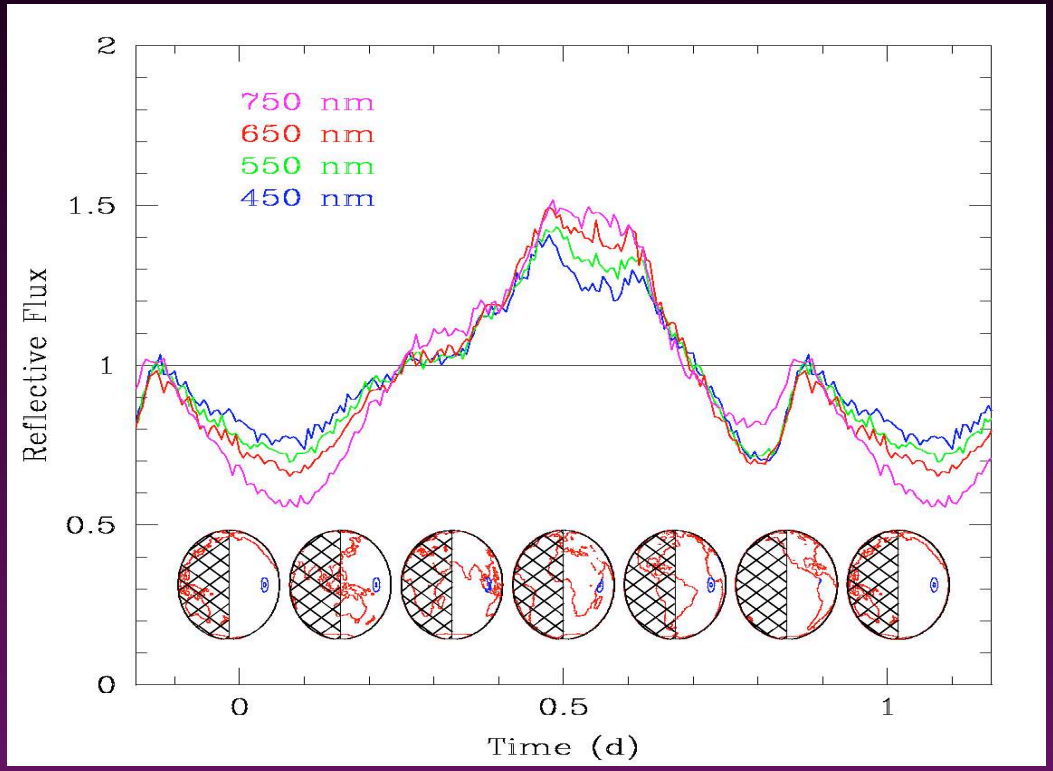






Sara Seager, CIW, now MIT

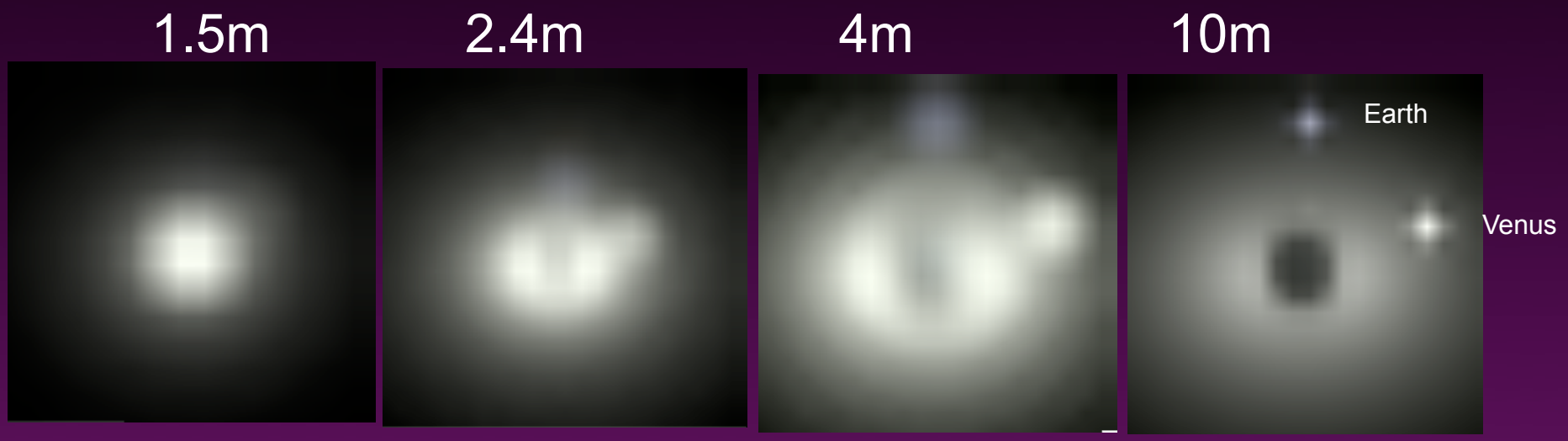
Photometry



Calculated Photometry of Cloudless Earth as it Rotates

It Should Be Possible to Detect Oceans and Continents!

Resolution Matters



ATLAS-T Study, M. Postman, PI

ATLAS 8-m

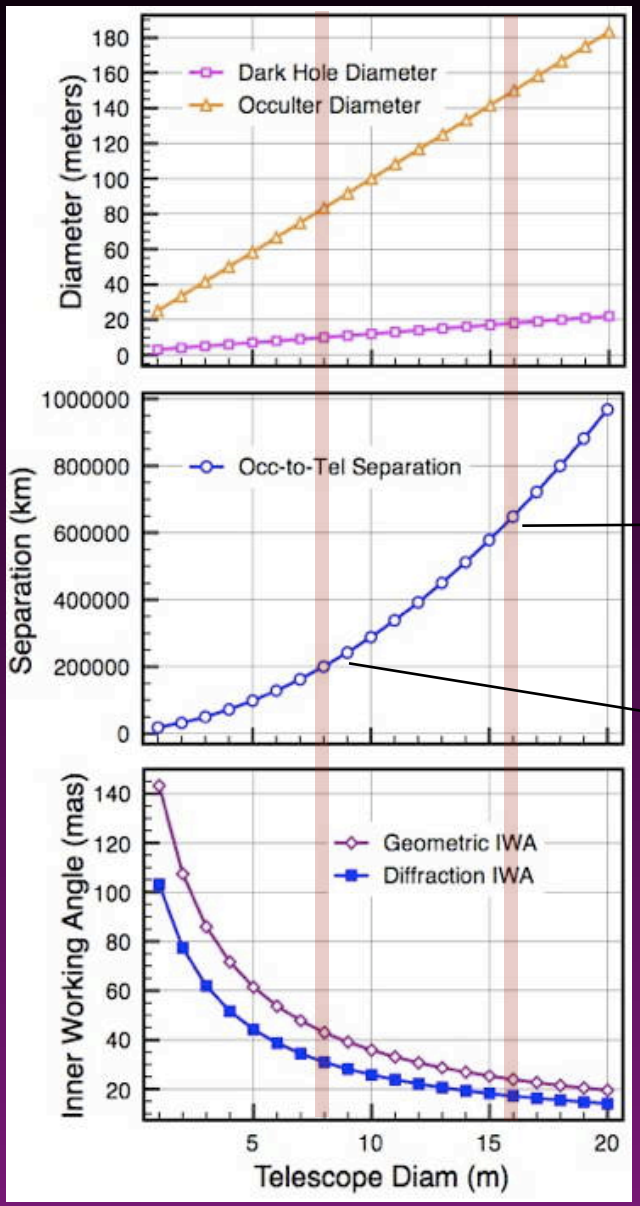
HST 2.4-m

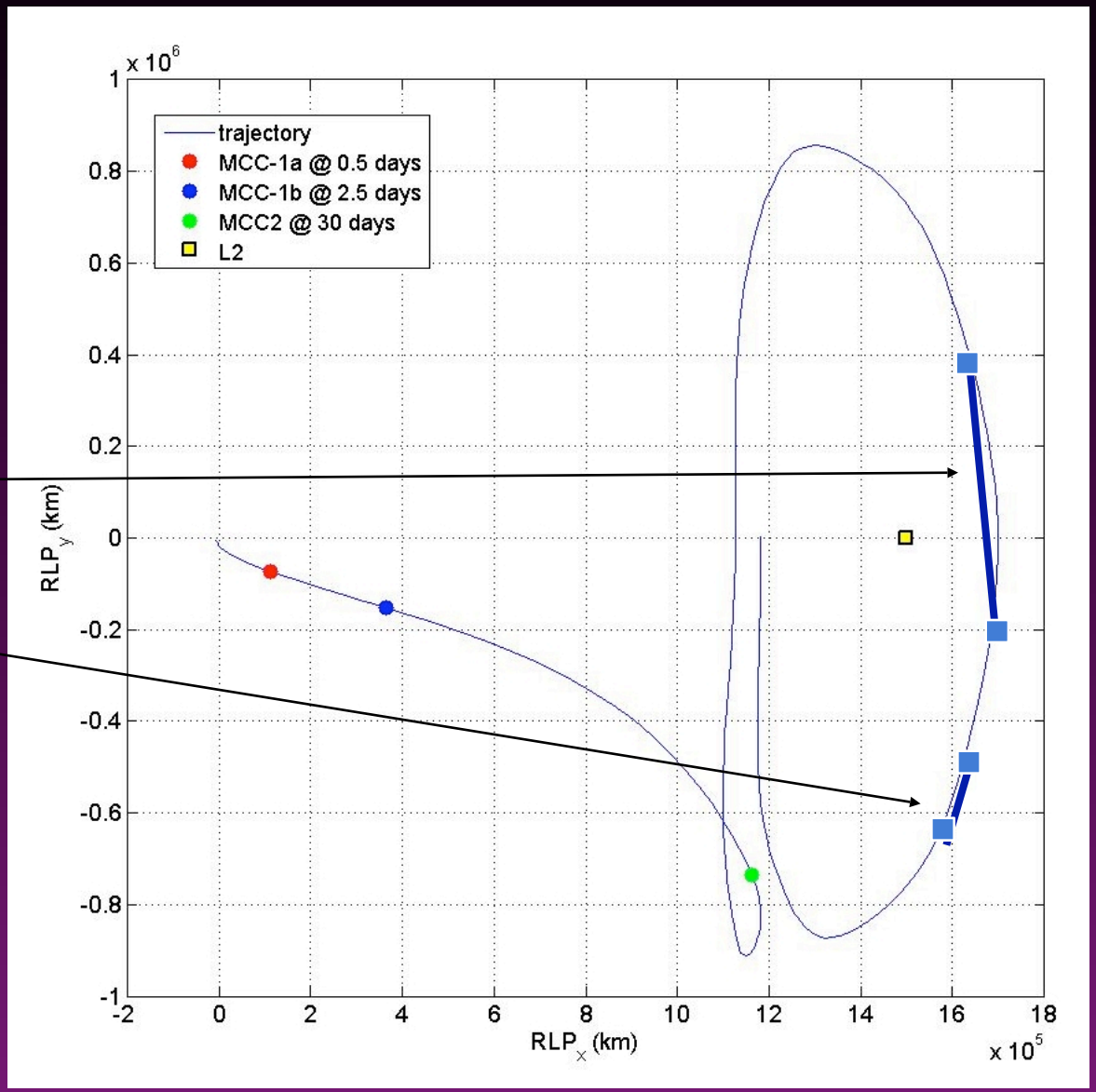
ATLAS 16-m

JWST 6.5-m

10-meters

Long Separations for Large Apertures





Rick Lyon, NASA GSFC

JWST Flight Dynamics, Conrad Schiff, NASA GSFC

The New Worlds Imager Concept

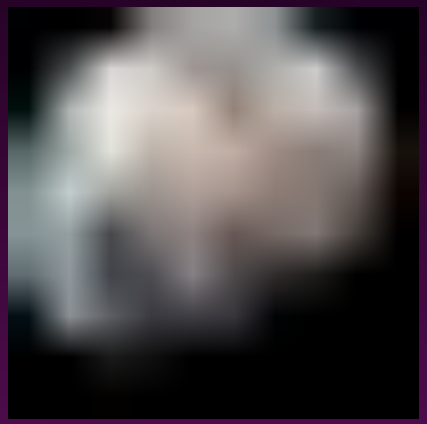
Earth at 200km resolution. Oceans, continents and clouds are visible.

Young Water Planet

JPL

True Planet Imaging

3000 km



1000 km

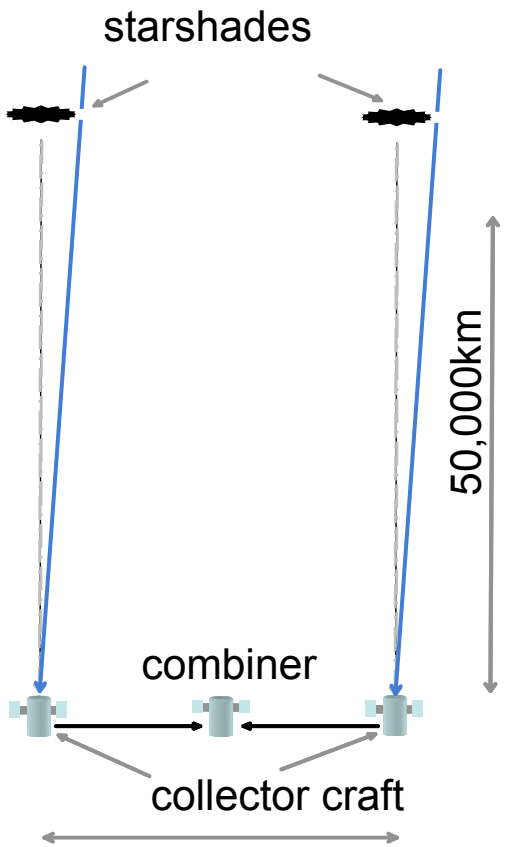
300 km

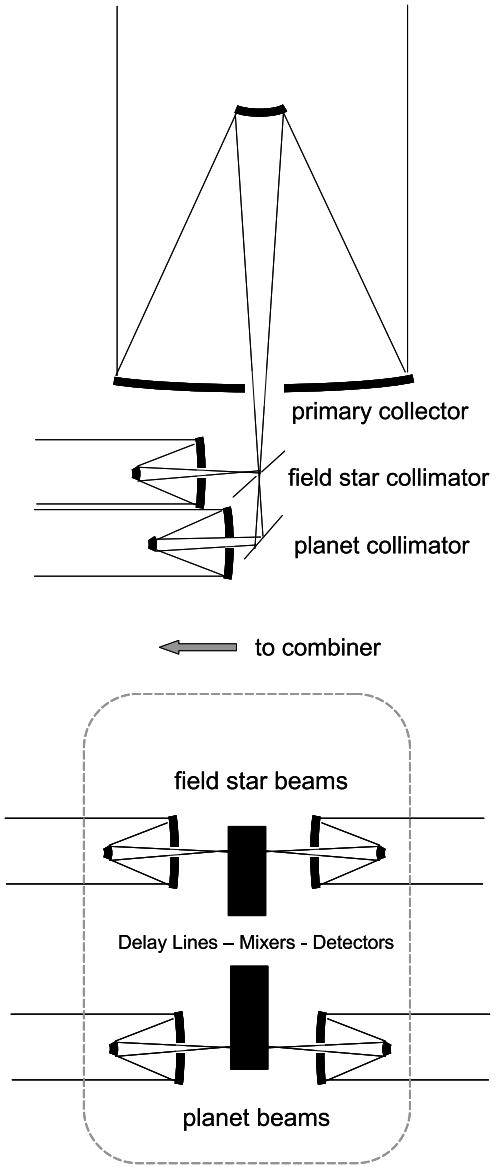
100 km

Earth Viewed at Improving Resolution

Solar System Survey at 300km Resolution

New Worlds Imager (NWI) Concept

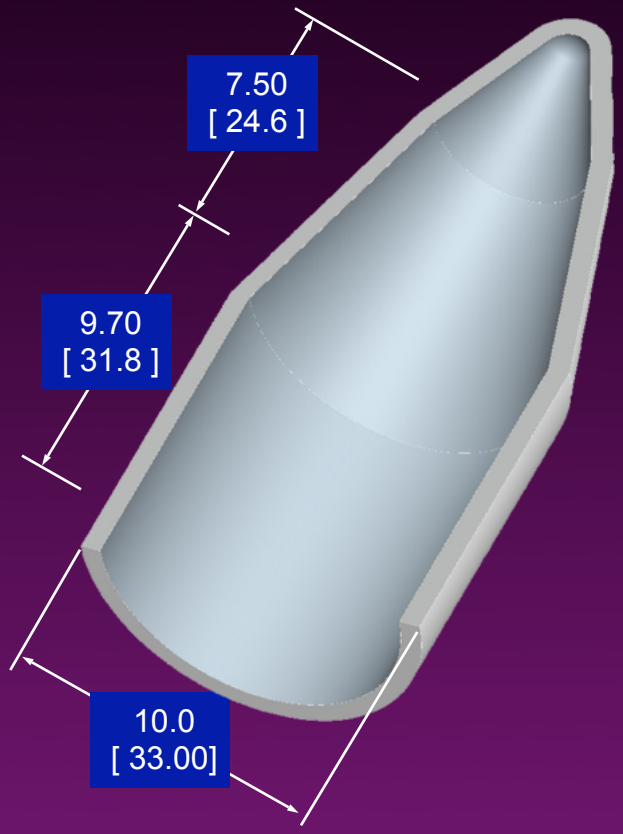




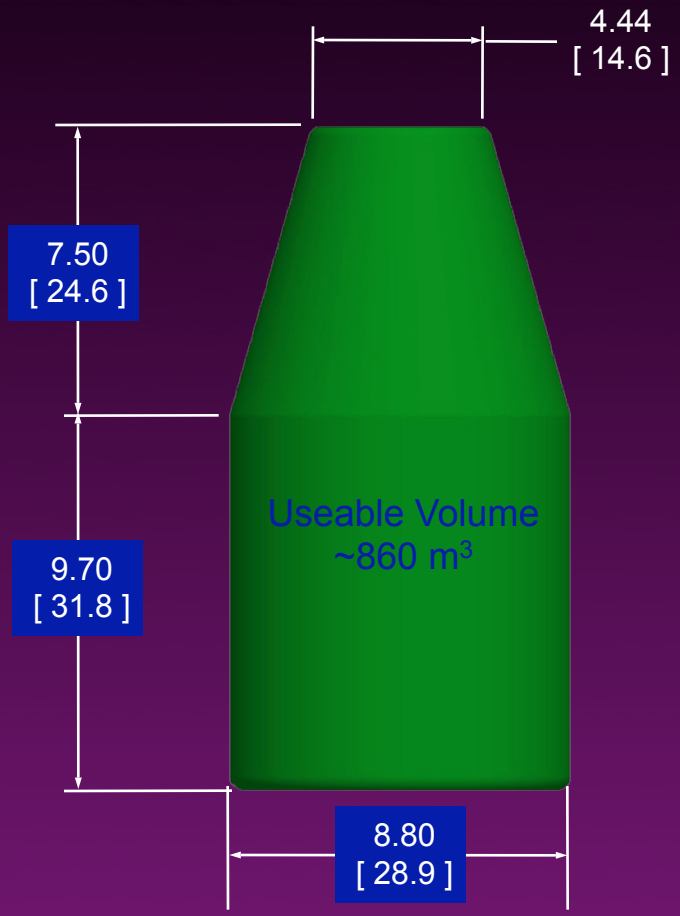
* 150 km separation is ~3 picroradian resolution at 500 nm, ~1000 km at 10 parsec
* 1500 km separation is ~0.3 picroradian resolution at 500 nm, is ~100 km at 10 parsec

Current Ares V 10 meter Shroud

Shroud Dimensions

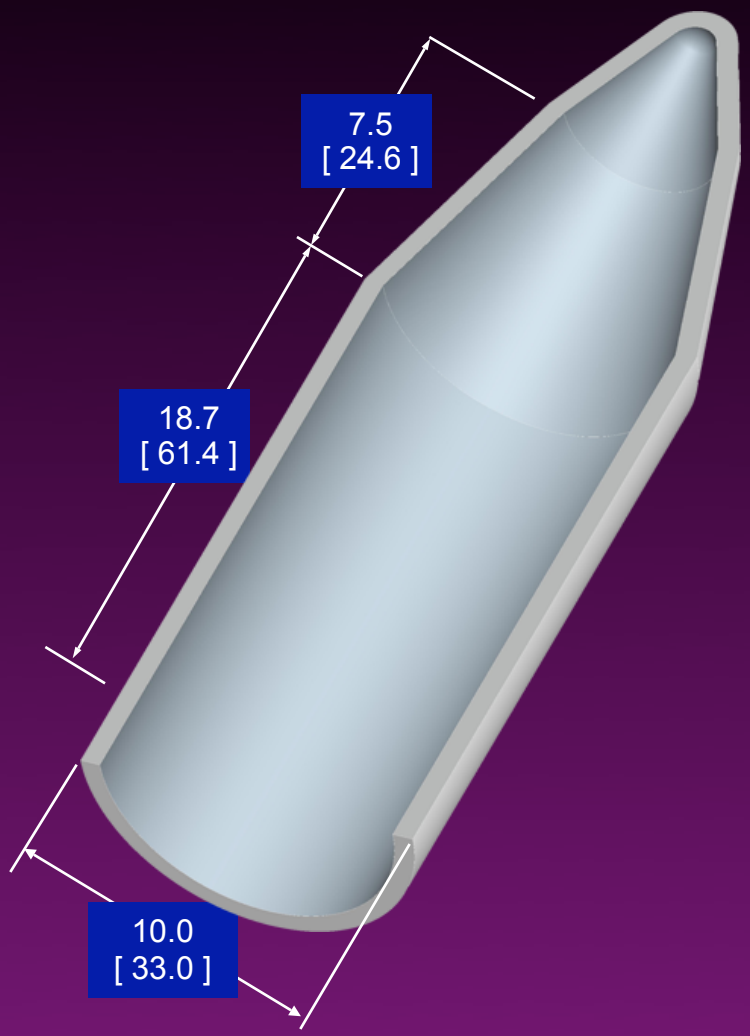


Usable Dynamic Envelope



meters [feet]

Notional Ares V Shroud

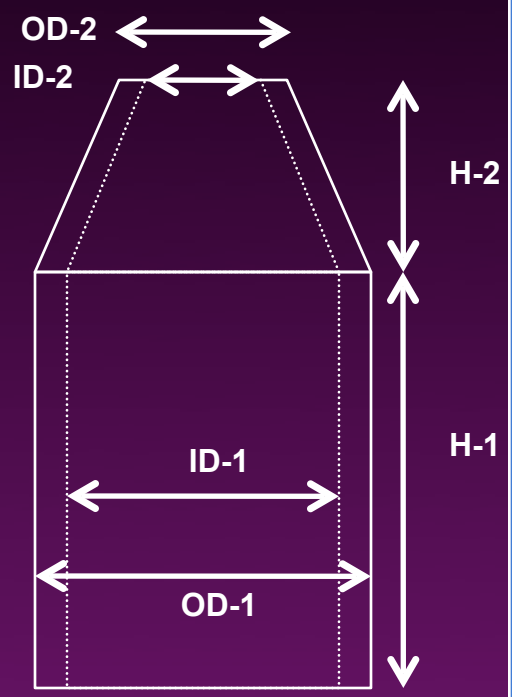


meters [feet]

* **Note:** The height of the shroud is limited by the height of the Vertical Assembly Building (VAB)

Ares V Preliminary Shroud

ID is the payload dynamic envelope, not the wall thickness.



Space Shuttle Payload
Volume = ~ 300 m3

Shroud Outer Diameter	10-m	10-m Long	12-m	
Shroud Mass	7.8	TBD	12.5	mT
OD-1	10	10	12	m
ID-1	8.8	8.8	10.3	m
H-1	9.7	18.7	12	m
OD-2	5.6	5.6	6.9	m
ID-2	4.4	4.4	5.2	m
H-2	7.5	7.5	9	m
Total Height	17.2	26.2	21	m
Volume	860	1410		m3
Payload to L2TO	55.8	TBD	58.1	mT

baseline

NOTE: all shroud dimensions are preliminary, are subject to change.

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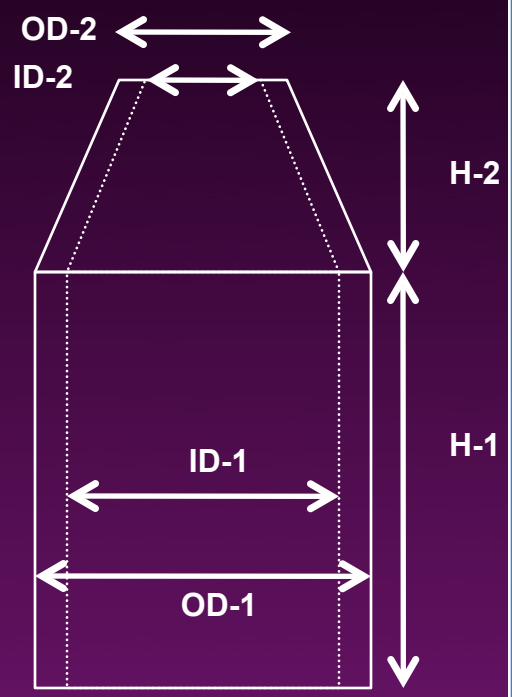

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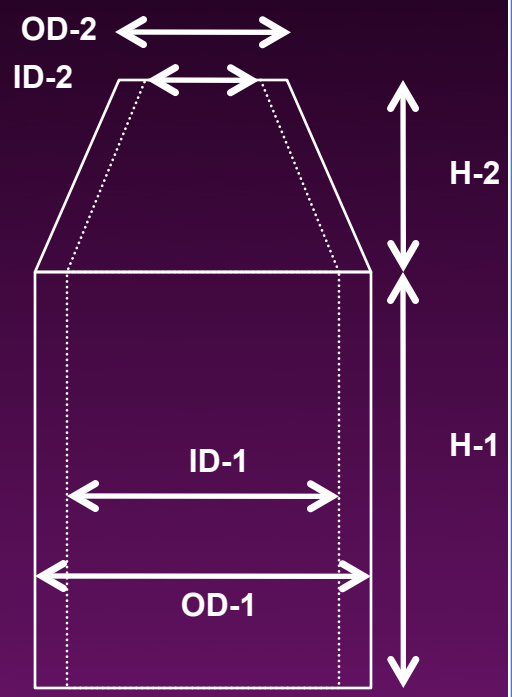

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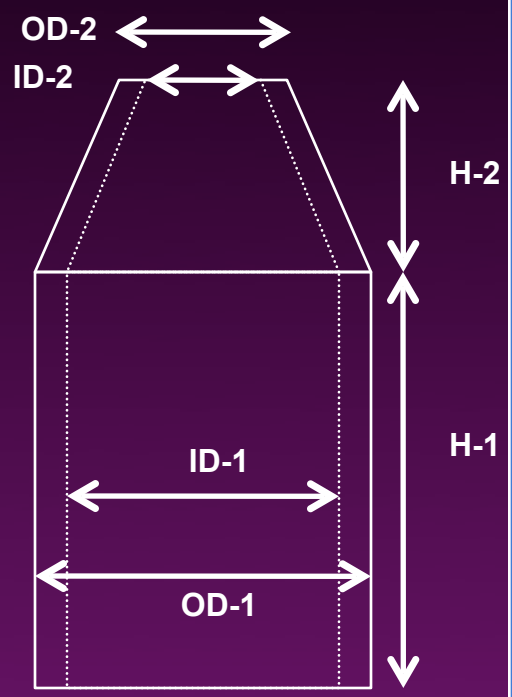

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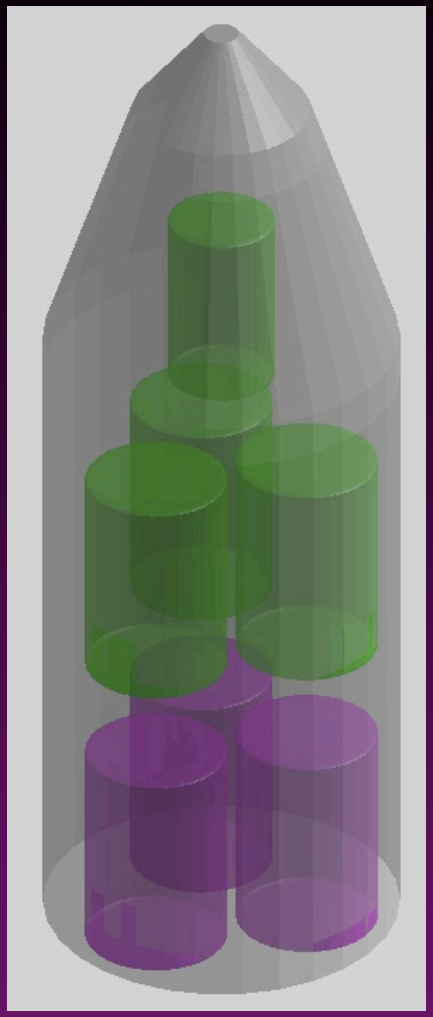
Fitting in the Ares V

1 Tel
2 Shades

2 Tels
4 Shades

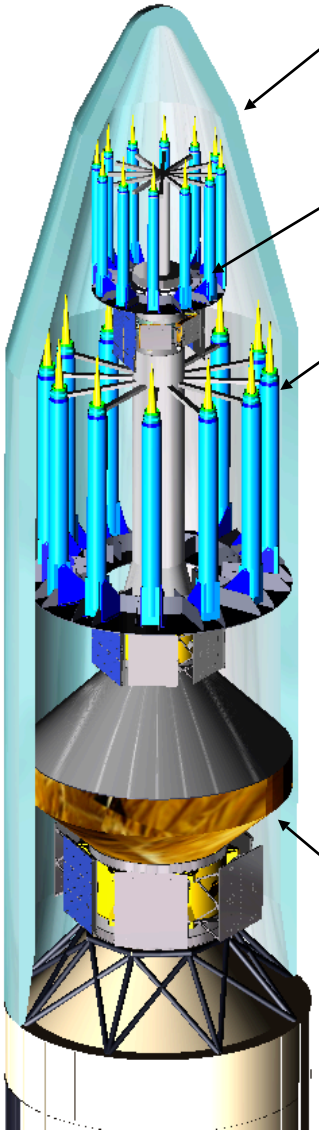
2 Tels
2 Shades
1 Combiner



3 Tels
3 Shades
1 Combiner

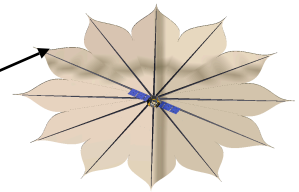
New Worlds Dual Occulter/Telescope Assembly Concept For An Ares V Launch

NORTHROP GRUMMAN

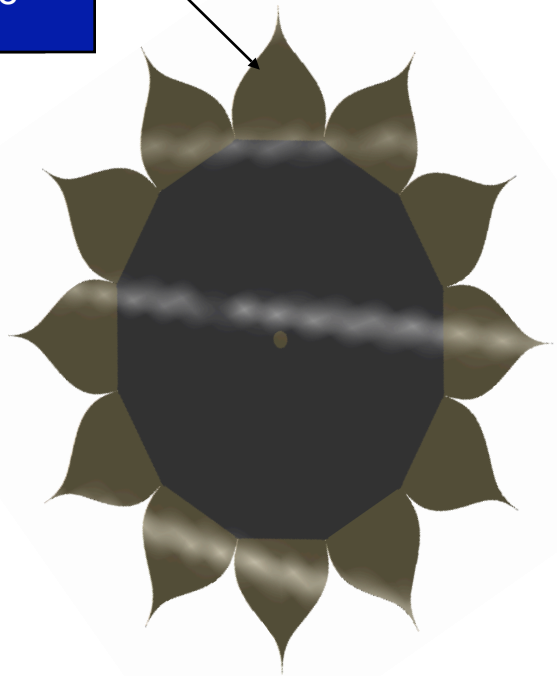


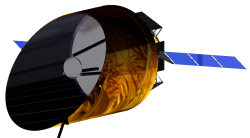
Ares V "Notional Fairing"

50 Meter Occulter Spacevehicle



100 Meter Occulter Spacevehicle





8 Meter Telescope Spacevehicle

Summary

- **Starshades enable planet characterization with "normal" telescopes**
  - Multiple starshades provide efficiency and observation tailoring
- **Ares V enables large volume and throw mass**
  - To L2 or drift-away orbits
- **Ares V launches loaded with multiple telescopes and starshades enable:**
  - Single telescope (8m) and two starshades
  - Two telescopes (4m) and four starshades
  - Imaging Interferometer: Combiner fed by two or three collector telescopes with starshades

An idea: Taking the Bus to L2

- **Ares V can launch 6 EELV payloads**
  - 4.2 m x 3 fits in 8.8 m ID, on two levels
  - 7 mt each x 6 = 42 mt + support frame (<12 mt)
  - Support frame mimics EELV PAF
  - 4.57 m x 3 + frame margin + dyn env. > 10 m fariing
- **Design for Atlas/Delta/Ariane/AresV**
  - Design for common, decide later
- **Fly on either one or "take the bus"**
  - Robust to failure or politics "outages"
- **Program Concerns**
  - Getting payloads to the pad at the same time
  - Schedule driven…"the bus is leaving"
  - A decade of discovery "eggs in one basket"